Ministry of
Transportation and
Communications

Ontario

REPORT EM-55

WELL WATER TESTING

Engineering
Materials
Office

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Engineering Materials Office
Chemicals Section

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WELL WATER TESTING

Introduction

In an effort to prevent, minimize, contain, alleviate or eliminate well water salt contamination originating directly or indirectly from Ministry winter road maintenance or construction programs the Ministry is deeply involved in water and, to a much lesser extent, in soil testing activities.

This report lists and explains in chronological order the various activities associated with the testing of well waters and for which activities the Chemicals Section of the Engineering Materials Office has the direct responsibility.

Background Information

Salt contamination of water wells may originate from storage of *"spiked"* sand or chemical de-icers, such as rock salt and calcium chloride, from the application of these materials for winter road maintenance, or from the application of calcium chloride (in liquid or solid form) as dustlaying agent. Spiked sand is rock salt enriched sand (approx. 100 lbs. salt/ton of mix); the salt is added to prevent lump forming through freezing of moisture present in the sand.

The Chemicals Section analyzes yearly 600 - 800 water samples from private wells and 500 - 600 water samples from Ministry wells (located at patrol yards, weigh scale sites and picnic sites).

The water testing programs can be divided into four categories following the purpose for which they are tested; these are:

a) To provide the Claims Office at Downsview and various Regional offices with information necessary to validate claims or complaints from well owners, to assess damages to property (viz. well, plumbing, garden plants or trees, etc.) and to initiate corrective measures.

b) To assist the (Regional and Head Office) Environmental Office in water quality monitoring programs that have been (and are being) initiated in an effort to determine the effect of road construction, road maintenance and traffic on the quality of well waters or waters from natural waterways in the vicinity of selected roadways.

c) To assist the Engineering Research and Development Branch in case studies that will, hopefully, result in corrective and preventive measures to alleviate, eliminate or prevent salt contamination from Ministry construction and winter road maintenance programs.

d) To obtain, through regular spring and autumn monitoring of patrol yard well water qualities indications of a start, success of containment or elimination of salt contamination at their locations of origin (viz. sand piles or storage domes).

Clients and Parameters of Analyses

More than 98% of all private well waters are tested under the previously listed category a ; the remaining 2% are tested under categories b and c.

As mentioned before, category d involves only water samples from M.T.C. owned wells; occasionally, in case of investigations, a limited number of water samples from natural water sources (viz. ponds, creeks, rivers) may be included.

Requests for analyses of water samples from private wells come from either the Regions (90%) or the Claims Office (10%).

The Regions require the water analyses for:

- contamination investigations relating to complaints or claims from private well owners who believe that the quality of their well water has been adversely affected by winter road maintenance or construction projects.

- pre-cautionary investigations or establishing a well data bank that involves gathering of well water data prior to the start of construction projects that may possibly affect the water quality.

The Claims Office requires water analyses for:

- the above mentioned reasons, and, additionally.

- to obtain well water data to monitor the effectiveness of corrective measures taken to eliminate or alleviate existing salt contamination problems.

The complete chemical analysis of a well water sample covering the major inorganic solutes involves usually ten individual determinations: pH, alkalinity, and the total hardness, chloride, sulphate, iron, calcium, magnesium, sodium and nitrate contents. Occasionally an extra two determinations may be required: specific conductance and the sulphide content.

These ten to twelve parameters are required to determine the source and location of contamination, identify or indicate the type of contamination (generally rock salt or calcium chloride) and to obtain indications of possible side reactions (ion exchange reactions between salt contaminated water and adjacent soil) that may result in marked increases in total hardness contents and associated "nuisance" complaints.

Testing of water samples from M.T.C. wells is routinely performed twice a year, in the spring and autumn. The purpose is to obtain *"early"* indications of salt contamination by leachates from sand and salt storage before the contamination has the time to spread to neighbouring private properties, to monitor *"clean housekeeping"* in the storage areas and to obtain information on the effectiveness of the use of salt domes. M.T.C. well waters are usually analyzed for six parameters only: pH, and total hardness, chloride, sodium, iron and nitrate contents.

Test Methods

The test methods are common standard methods listed in any analytical chemical reference book of methods. The test methods followed in the Chemicals Sections are:

Test	Type of Test	Reference
Total hardness	EDTA titrimetric	Standards Methods for the Examination of Water and Waste Water-prepared and published by: American Public Health Assoc. American Water Works Assoc. American Pollution Control Fed.
Calcium	EDTA titrimetric	"
Magnesium	EDTA titrimetric	"
Alkalinity	titrimetric	"
Chloride	argentometric	"
Sulphate	gravimetric	"
Iron	colorimetric	"
Sodium	flame photometric	"
Sulphide	iodometric	"
Nitrate	Brucine colorimetric	Standard Methods of Chemical Analysis-Welcher Volume II B
pH	Instrumental	"

Test Reports

Analyses of water samples tested under category a of the water testing programs are reported to the requestor(s) of the analysis with a copy to the Head of the Claims Office. The test report lists the test results in an Appendix (Appendix 2) and provides, where possible, comments on the test results. The test report indicates whether the sample is:

- satisfactory for human consumption, viz. the major solutes are within the limits recommended by the M.O.E. with no trace of contamination.

- potable, viz. the major solutes are within the limits recommended, but one or more of these solutes are elevated as a result of contamination.

- unsatisfactory for human consumption, viz. one or more of the major solutes exceed the recommended limits.

In addition to the above *"suitability for human consumption"* rating, the test report will, where possible, indicate whether any elevated concentration of solute is or may be related to M.T.C. operations or whether the condition represents the natural background level of that specific solute at the location in question.

Analyses of water samples tested under categories b and c of the water testing programs are mainly part of monitoring programs and require *"interpretation"* only occasionally. They are usually reported on special monitoring sheets (Appendix 3) and only to the requestor(s) of the testing program.

Analyses of water samples tested under category d are, as mentioned before, also part of monitoring programs. They are reported to the District Hwy. Services Supervisor with a copy to each member of the Contamination Control Committee.

The *"category d"* test results are also entered in the so-called Special Files. These files have all pertinent information on every M.T.C. patrol yard and weigh scale site water well (viz. well driller record, water analyses, drawing of the patrol yard site, etc.).

These test results are only used to obtain, in most cases, a warning of a start of salt contamination and need commenting only occasionally. The words *"in most cases"* have been used as it is possible that salt contamination may have started through leaching from the sandpile, or salt dome or shed, but that it remains undetected for a certain length of time because surface or subsurface drainage and ground water flows lead away from the existing M.T.C. well.

Interpretation of and Comments on Test Results

In order to be able to comment on the test results obtained one will have to know the average analysis of an uncontaminated water. The Chemicals Section compiled such an analysis and uses it as a standard (Appendix 1) with which all water sample analyses are compared.

In addition to rating the water sample's suitability for human consumption, a chemically trained person will, with the use of the standard analysis, be able to comment on deviations of the compounds tested. He will be able to explain the cause of any deviation from the standard analysis, conclude with a reasonable degree of accuracy whether the contamination is man made or whether it is the result of natural background composition, state whether it is mild or severe, possibly whether the contamination results from storage of winter road maintenance materials or from application of these materials on road ways.

In a very general way the comments that can be made with respect to the test results obtained can be grouped together.

However, it will require a chemically trained person to sift through these comments to select those relevant to a specific condition and to possibly elaborate on these.

The following comments may be used as guidelines in *"interpreting"* the test results obtained:

pH

Practically all water samples tested have pH values from 7.0 - 8.5. In case of much lower or higher pH values, say less than 6.5 and greater than 9, the source of sampling shall be commented on.

If the pH value is less than 6.5 and the source or area of sampling is industrial, chances are that an acidic effluent may be the cause of the acidity and this warrants further investigation.

If the source or area of sampling happens to be the countryside one may safely conclude that the relatively low pH is caused by the presence of organic acids or tannin derivatives that originate from peat or muskeg. Confirmation can be provided by testing the sample for the presence of organic matter.

If the pH value approaches or exceeds 9 one may assume that free caustic is present and the source is probably industrial. The source shall be investigated.

Total Hardness

This is the sum of permanent hardness (viz. calcium and magnesium carbonates, sulphates or hydroxides) and temporary hardness (viz. calcium and magnesium bi-carbonates).

High hardness contents are the cause of so-called nuisance complaints that are associated with non-lathering of soaps, scale forming in toilet bowls and water reservoirs, relatively short life spans of hot water tanks and water lines, film forming on glassware (especially on lead containing crystal ware); high hardness contents are often blamed for reduced enjoyments of beverages such as tea and coffee.

Hardness of well water is a natural phenomenon. However, the degree of hardness may be contributed to by ion exchange processes that take place in the soil. In these processes sodium ions from a salt contaminated water are exchanged for hardness ions from the soil (viz. calcium and magnesium) in the vicinity of the water well. This exchange process is comparable to the regeneration process of the ion exchange media of a water softener. The result of the ion exchange process is that salt contamination of the water source may also increase the number of legitimate nuisance complaints related to increased (often to extremely high levels) hardness of the water. The rate and/or degree of ion exchange depends on several factors such as salt content of the water, texture of the soil, type of soil, speed of ground water movement, etc.

The determinations of total hardness, chloride and sodium contents usually enable a calculation of the sodium content that has been exchanged and the increase of the total hardness content caused by the ion exchange.

The calculation is as follows:

1/ Calculate the sodium content based on the chloride determination.

2/ Substract the sodium content of the actual sodium determination (by flame photometry) from the sodium content as calculated in (1). The difference is the sodium content that has been exchanged.

3/ Convert this sodium content to its chemical equivalent in terms of calcium carbonate (viz. exchange of two sodium atoms for one calcium atom and conversion of the calcium so obtained to calcium carbonate).

Method:

$$\frac{\text{Sodium content from (2)}}{2 \times 23} \times 40 \times 2.5 = ____ \text{ ppm } CaCO_3$$

contributed by ion exchange

If the sodium content of the actual sodium determination (by flame photometry) is larger than the sodium content calculated from the chloride determination (1), the ion exchange process is absent or its rate is negligible. The total hardness content determined has, in that case, not been affected by the salt contamination of the water; the total hardness content determined is the natural background level for the location of the well.

Chloride

Chloride levels greater than 35 ppm Cl^- are caused by salt contamination.

In extremely rare cases chloride contamination may be caused by natural phenomena such as old ocean beds or natural calcium or sodium chloride brines, but in 99% plus of all water samples tested elevated chloride levels are associated with winter road maintenance (sanding and salting) or construction and *"summer maintenance"* (dustlaying) operations.

If a water source is chloride contaminated, the chloride is generally present as either sodium or calcium chloride with potassium chloride as a quite distant possibility (and in this case only as a natural occurrence).

Sodium chloride is a strong electrolyte [meaning it is a salt of a strong acid (HCℓ) and a strong base (NaOH)], stronger than calcium chloride [which originates from a weaker base $(CaOH)_2$]. Sodium chloride solutions are, therefore, more aggressive (corrosive) than calcium chloride solutions of equivalent strengths. Any comments made on the corrosiveness of a given well water shall refer to this characteristic.

Elevated chloride contents are as mentioned before, aggressive and corrode kitchen utensils, water pumps and lines hot water heaters, etc. They also affect health problems in that they are harmful to persons with renal troubles.

Although the M.O.E. guidelines list a criterion of 250 ppm Cl' as the recommended maximum limit, it is a recognized and accepted fact that chloride contents of much less than the acceptable limit may be harmful to persons with specific health problems. Elevated chloride contents of well waters are practically always accompanied by elevated sodium contents (the only exception is if contamination is caused by the use of calcium chloride used as dustlaying agent). It is this Ministry's policy (Directive B-65) to advise property owners with well water exceeding 20 ppm sodium (Na) to consult their physicians on the use of such water for cooking or drinking purposes. Such advice is given without, in any way, accepting liability or suggesting liability of another party.

Sodium

The M.O.E. follows a criterion of 20 ppm Na for use in drinking water. At and above this limit they usually advise well owners to consult their physicians with respect to water quality.

It is known that elevated sodium contents may be harmful to persons with cardiac and hyper-tension problems. Elevated sodium contents (viz. exceeding 20 ppm Na) are not always

caused by salt (viz. sodium chloride) contamination. Sodium is commonly present in water as a *"natural background"* compound such as sodium sulphate, carbonate or bi-carbonate.

If the sodium content is elevated but the chloride content very low, one may safely conclude that the sodium is present as a *"natural background"* compound.

If sodium and chloride contents both are elevated, the sodium is definitely introduced as sodium chloride. Even so, as previously explained under *"Total hardness"*, it is possible that the sodium content determined is less than what may be expected from the chloride determination. This is generally caused by the previously mentioned ion exchange processes. The calculation for the amount of sodium exchanged is as given under the calculations previously listed for *"Total hardness"*.

Sulphate

Sulphate in well waters is generally present as a natural background compound. The *"Standard Analysis"* shows that this compound is generally present in a concentration of less than 30 ppm SO_4"; the M.O.E. follows a recommended limit of 250 ppm SO_4". High sulphate concentrations together with elevated magnesium contents may cause cathartic effects especially to the casual users.

High sulphate and high hardness contents are generally cause of complaints with respect to film forming on glassware (important to restaurants) and the taste of beverages such as tea and coffee.

Iron

Iron in well water may be present as a natural background compound or it may have been introduced to the well water due

to bacterial action, from rusting of metal parts of the water pump and water lines or from leachate from iron containing backfill.

Iron in well water is not generally considered harmful for human consumption and the M.O.E. criteria of 0.3 ppm Fe has been mainly set for aesthetical reasons. Iron is originally present as bi-carbonate, carbonate or silicate which compounds are soluble and colourless.

Upon exposure to air these compounds are oxidized and converted to mixtures of di- and tri- valent iron hydroxide, which is a dark brown (sometimes blackish) insoluble compound of fluffy appearance.

High iron contents are mostly associated with nuisance complaints such as appearance of brown stains in toilet bowls, and sinks, yellow laundry, brown precipitates in a glass of drinking water, etc.

It is generally rather difficult to identify or obtain indications as to the cause or source of iron problems which, as previously mentioned, may or may not be related to M.T.C. operations.

The following listing may serve as guide:

1/ investigate if there has been any dynamite blasting in the vicinity. Dynamite blasting sometimes opens fissures that seem to contain iron laden waters that then leach into the existing water table. This type of problem is frequently of temporary nature only, seemingly because the iron contaminant is limited in volume and dissipates (through dilution) into the water table.

2/ newly drilled or deepened wells often follow the same pattern (as under 1).

3/ Investigate if iron containing land fill has been used and if any leachate is able to enter the well.

4/ Investigate if there is any unpleasant odour associated with highly iron contaminated water. If so, chances are that iron bacteria may be present.

5/ Investigate if there is a salt contamination problem. If so, there is a possibility than an elevated iron content is caused by corrosion of metal parts of water pump, water heater or water lines.

Nitrate

Nitrate contents exceeding the M.O.E. limit of 10 ppm N shall be reported to the nearest M.O.H. office and it shall be left up to them to do any follow-up if they deem it necessary. High nitrate contents are associated with certain infant diseases.

Elevated nitrate contents are not usually caused by M.T.C. operations. The most probable causes for elevated nitrate contents are:

- decaying vegetation or other organic matter in close proximity of the water well
- leachate of fertilizer applied in the vicinity of the water well

There are probably only two cases in which high nitrate containing well water may be directly affected by M.T.C. operations. These are:

- leachate from nitrate containing land fill used in the immediate vicinity of the well
- dynamite blasting in the general location of the well which may have opened up fissures that allows nitrate containing leachate to enter the well or the water table

Sulphide

Hydrogen sulphide is a colourless gaseous compound with an objectionable odour (viz. rotten egg smell).

Sulphides and poly-sulphides are present in well waters through leaching of decaying organic material into the well, through leakage from fissures opened up by dynamite blasting, or they may be present in the groundwater as natural background compounds.

Sulphides, and especially poly-sulphides, tend to cause black or very dark brown coloured stains and jelly-like sedimentation through reactions with iron. In their original state they are gaseous compounds that tend to be driven out by heat. Accordingly they cause bad odours especially of hot water in areas of sulphide contamination.

Prolonged exposure to even minor concentrations of sulphides, such as in equipment garages after washing of equipment with sulphide contaminated water, may cause headaches (ranging from slight to quite severe).

Water Treatment

Most waters can be treated to eliminate or reduce objectionably excessive concentrations of the various compounds present. Although it is advisable to consult the proper authority on the subject, it is helpful if one has at least an idea of the type of treatment equipment that may be required to treat a water for specific problems.

The decision as to the type and cost of treatment equipment required is, of course, generally based on cost-benefit analyses although it may sometimes be dictated or influenced by other considerations.

The treatment processes generally are:

- Water softening

Softening is required to reduce high hardness to acceptable levels. The ideal hardness content to be aimed for is approximately 50 ppm $CaCO_3$.

It must be realized that reducing a high hardness content to acceptable levels through the normal softening process increases the sodium content (through exchange of calcium and magnesium from the water for sodium from the softener's exchange medium) to possibly unacceptable levels.

During the softening process the exchange medium will decrease in exchange capacity and this will result in an increasing conductivity of the treated water. Most softeners are presently automated to the extent that they will automatically start the regeneration cycle of the softening medium when the conductivity of the treated water has been increased to a certain level. The softening medium is regenerated by *"reversing the ion exchange"* through the use of saturated salt (NaCl) solution followed by rinsing of the excess salt solution with clean (uncontaminated) fresh water.

Repair services to the equipment are generally contracted out.

- Chlorination

Chlorinators, as the word indicates, add chlorine solutions to the water being treated. Chlorine is an oxidizing agent and chlorination is, for instance, used for treatment of waters with iron or sulphide problems. Through chlorination di-valent iron is oxidized to tri-valent iron (thereby facilitating filtration) and sulphide is oxidized to free sulphur, a yellow crystalline compound; the iron hydroxide and sulphur are then removed by filtration.

The active component of the chlorinating solution is sodium

hypochlorite (NaOCℓ) and the treatment solution is prepared in the required strength utilizing commercially available 6% or 12% NaOCℓ stock solutions.

Maintenance and most of the repair service for the chlorinator and preparation of the treatment solutions required are easily looked after even by a person with limited technical abilities.

- Filtration

Suspended or settled solids, irrespective of appearance mode or particle size, are removed by filtration. This means that solids as diverse as sand or silt and fluffy tri-valent iron hydroxide are removed in the same fashion with perhaps only the particle size of the filter media, the diameter and height of the filter bed differing depending on the type and concentration of solids to be removed. The filter medium is usually Ottawa sand if the filter is of the so-called backwash type.

There are, in addition to the above sand filters, so-called cartridge filters available. These are generally of the "throw away" type and, therefore, quite modestly priced. They are not as efficient as the previously mentioned sand filters and are commonly used to remove relatively low concentrations of solids.

Many persons who have their well water chlorinated object to the taste and odour of the residual chlorine (viz. chlorine still present in the water after the filtration stage). This residual chlorine may be removed by passing the water over an activated charcoal filter through adsorption of chlorine by the "porous" charcoal. The activated charcoal is only good for a limited time, cannot be regenerated and can only be replaced.

Maintenance and repair service to the equipment is generally contracted out.

- Reverse osmosis

Solutes (or dissolved solids) such as sodium, chlorides, sulphates, nitrates, etc. can in practice be removed only by distillation or reverse osmosis. Of these two processes the most economical one for this country is reverse osmosis.

Osmosis is a natural process that separates a solvent from a solvent-solute system through utilization of a semi-permeable membrane (an example is the intake of nourishment through plant roots). This process can be stopped or reversed by applying a force equal to or in excess of the osmotic pressure of the solvent-solute system. Reverse osmosis is caused by the application of a pressure large enough to reverse the normal osmotic flow to the concentrated side of the semi-permeable membrane (viz. instead of having solvent flow through the membrane from a solvent-solute system of lower concentration to that of a higher concentration, have the solvent flow reversed).

Reverse osmosis units for residential use are presently commercially available. The draw backs are relatively high purchase and maintenance costs. Also, reverse osmosis treatment often requires pretreatment of the water through softening, chlorination or filtering to protect and prolong the life span of the semi-permeable membranes.

An additional characteristic of reverse osmosis treatment is that the treatment unit can, at its best, only remove approximately 80 - 90% of the solutes present. This means that, if the end product is still not pure enough, a second unit is required. The second unit will then use the end product of the first unit as feed stock and will remove up to 80 - 90% of the solute present in it.

General Comments

It shall be noted that the water analyses performed by the

Chemicals Section cover only those (major) solutes by which one is readily able to identify the presence, cause and origin of contamination from de-icing or dustlaying operations.

There are, of course, many other compounds that may be present in water as pollutants. For instance, the Chemicals Section is occasionally requested to perform additional tests for compounds that may be present in water in low or even in trace concentrations, such as lead, tin, arsenic or copper. If the Chemicals Section is unable to perform certain analyses through lack of specialized equipment or related training it may (and it has done so on many occasions) call upon the expertise and testing facilities of the Ministry of the Environment with which this Ministry has a close working relationship that has benefited both Ministries (M.O.E. and M.T.C.) and the well owner whose property has been affected.

No figures are available to indicate the impact of the various water testing programs on the total number of claims and/or complaints, either concrete or potential, received in the Regions and the Head Office. However, it seems a safe assumption to state that it is probably considerable not only in the investigation, justification, settling or denial of claims, but also through the analytical chemical input necessary to monitor the effectiveness of preventive or corrective measures related to potential or existing salt contamination problems.

APPENDIX 1

Standard Analysis of Well Water

			M.O.E. Criteria
pH	7.0-8.5		6.5-8.5
ppm Total hardness (as $CaCO_3$)	less than 80	- low hardness	-
	80 - 180	- medium hardness	-
	greater than 180	- high hardness	-
ppm Chloride (Cl')	less than 35		250 max.
ppm Sulphate (SO_4'')	less than 30		250 max.
ppm Iron (Fe)	less than 0.3		0.3 max.
ppm Calcium (Ca)	less than 21	- low hardness	-
	21 - 47	- medium hardness	-
	greater than 47	- high hardness	-
ppm Magnesium (Mg)	less than 6	- low hardness	-
	6 - 13	- medium hardness	-
	greater than 13	- high hardness	-
ppm Sodium (Na)	less than 30		- *
ppm Nitrate (N)	less than 2		10 max.
ppm Sulphide (S'')	Nil		0.002 max.

* Although no limit is listed the M.O.E. follows an *"un-official"* limit of 20 ppm Na.

Ministry of Transportation and Communications
Ontario

APPENDIX

TEST RESULTS OF WELL WATER

Well Owner:_____

Location:_____

Lab. No.

Sampling Date

pH

ppm Total Hardness (as $CaCO_3$)

ppm Alkalinity (as $CaCO_3$)

ppm Chloride (Cl')

ppm Sulphate (SO_4'')

ppm Iron (Fe)

ppm Calcium (Ca)

ppm Magnesium (Mg)

ppm Sodium (Na)

ppm Nitrate (N)

ppm Sulphide (H_2S)

µmho Specific Conductance at 25°C

Appearance

NOTE: Total hardness of tap water in the Chemical Laboratory is approximately_____ppm $CaCo_3$.

ND = not determined.

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

APPENDIX 3

Engineering Materials Office
Chemicals Section

Laboratory data on:

Reported to:

Requested by:
Sampling date:
Sampling location:

Reported by:
Reporting date:
Our File Number:

Sampling Date										
Sample Identification										
Chem. Lab. Number										
pH										
Total Hardness (ppm $CaCO_3$)										
Alkalinity (ppm $CaCO_3$)										
Chloride (ppm Cl')										
Sulphate (ppm SO_4'')										
Iron (ppm Fe)										
Calcium (ppm Ca)										
Magnesium (ppm Mg)										
Sodium (ppm Na)										
Nitrate (ppm N)										
Conductivity at 25°C (µmho/cm)										

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